Contaminated Sediment Transfers in River Basins: Information for Understanding the System

Conclusions and Recommendations from WP2

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Talk Outline

Sources of contaminants.

Transfers of contaminants

Conclusions and recommendations from WP2

Sources

On a river-basin scale, what contaminant sources are of the most importance?

What tools do we have to determine this?

What do we need to develop to more effectively address these questions.

Contaminant Sources

Contaminant	Sources
Metals (Ag, Cd, Cu, Co, Cr, Hg, Pb, Sb, Sn, Zn, As)	Geology, mining, industry, acid rock drainage, sewage treatment, urban runoff.
Nutrients (N, P)	Agricultural and urban runoff, wastewater and sewage treatment.
Organic compounds (pesticides, herbicides, hydrocarbons).	Agriculture, industry, sewage, landfills, urban runoff.
Radionuclides (^{137}Cs, ^{129}I, ^{239}Pu, ^{230}Th)	Nuclear power industry, military, geology.

Contamination Sources

Point sources

- landfill site
- mine
- factory
- sewage treatment plant
- CSO
- Bedrock mineralisation

Relatively 'easy' to identify and control

Diffuse sources

- urban
  - metals, organics, salt
- agricultural
  - pesticides, fertilisers
- floodplain reworking
- geology
- groundwater

Hard to identify and control

Point Sources – *Industry e.g.* *Immissions to the Rhine*

1983-1987

Substance	Total	Switzerland	France	Germany
Cd [kg/a]	2705	220	710	1775
Cu [kg/a]	145685	11685	48000	86000
Hg [kg/a]	972	177	70	725
Pb [kg/a]	96230	2330	11500	82400
Zn [kg/a]	620310	17310	102000	501000

1993-1997

Substance	Total	Switzerland	France	Germany
Cd [kg/a]	<700	<95	242	336
Cu [kg/a]	38673	800	11190	26683
Hg [kg/a]	239	13	74	152
Pb [kg/a]	19113	<400	3120	15593
Zn [kg/a]	126885	7430	41100	78355

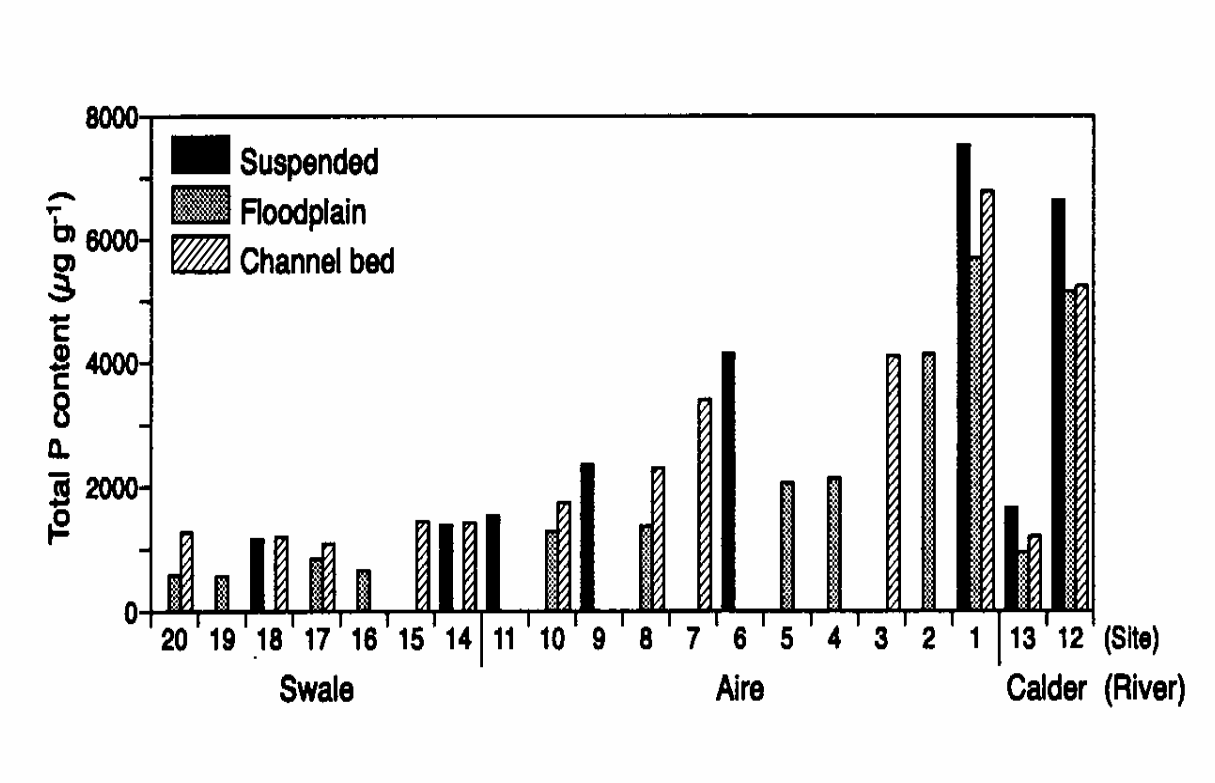
From: Salomons and Gandrass, 2001.

Diffuse Urban Sources

Major sources of contaminants from road runoff, waste water and industrial processes.

Overall, contributes a large diffuse source of contaminants.

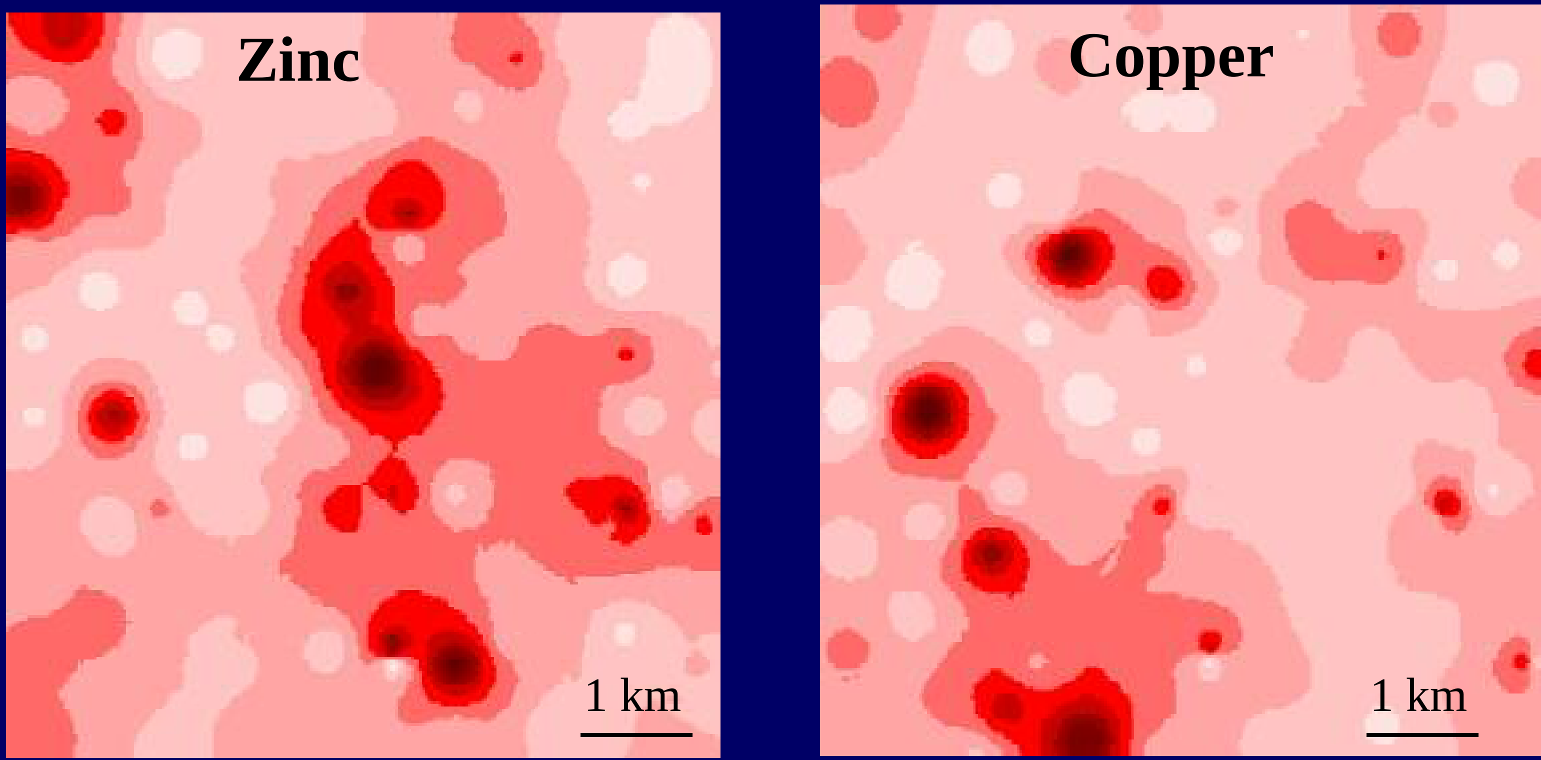
Diffuse Urban Sources, e.g. Phosphorus



Significant inputs of phosphorus to sediments seen downstream in major urban river basins.

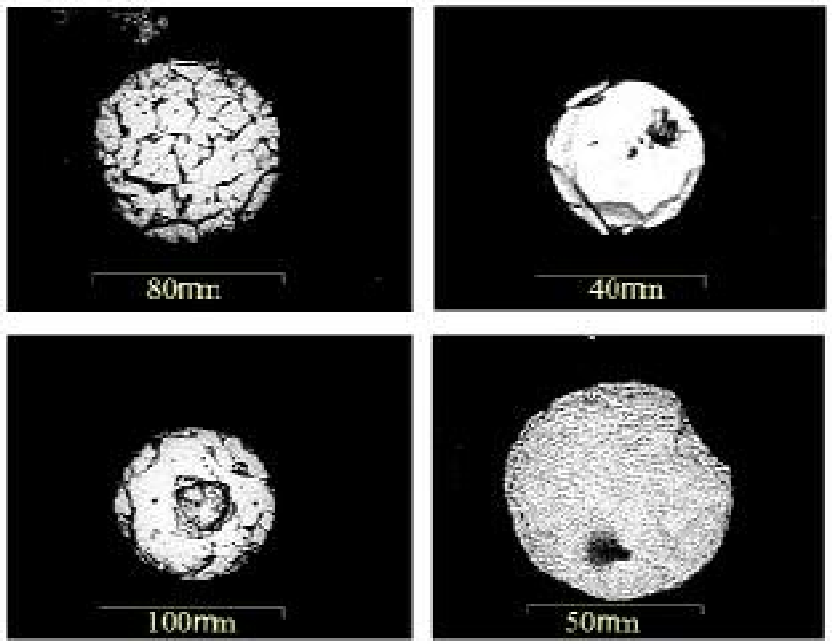
Owens et al (2001), *The Science of the Total Environment*, **266**, 177-186.

Diffuse Urban Sources



Diffuse urban sources of contaminants are highly variable on spatial scales

Diffuse Urban Sources, e.g. Complex Mineralogy



Urban sediment particles commonly possess unique mineralogy.

These grains host most contaminants.

Element	Iron oxide concentrations (μg/g^{-1})	Iron rich glass concentrations (μg/g^{-1})
Pb	247 - 1,554	214 - 696
Cu	387 - 1,460	274 - 3,252
Zn	406 - 9,597	216 - 5,341

Diffuse Sources – *Floodplains*

Floodplains act as major stores of fine grained sediment and associated high levels of contaminants.

Floodplains, therefore, act as long-term stores of contaminants. But these Stores may be released.

Diffuse Sources – *Remobilisation from Floodplains*

Floodplains store significant levels of contaminants.

Erosion of these floodplains releases these contaminants back to the river basin.

Diffuse Sources – *Floodplains*

Total floodplain storage in last 2000 yrs (kg)

River	As	Cr	Cu	Pb	Zn
Swale	3.0×10^5	2.4×10^6	8.6×10^5	3.0×10^7	1.3×10^7
Swale-Ure	9.1×10^6	9.5×10^7	2.3×10^7	2.7×10^8	2.6×10^8
Nidd	2.8×10^5	3.8×10^6	5.6×10^4	1.1×10^7	6.2×10^6
Ouse	7.0×10^6	6.6×10^7	1.5×10^7	1.8×10^8	1.6×10^8
Wharfe	7.5×10^5	6.4×10^6	2.1×10^6	2.4×10^7	1.9×10^7
Aire	2.1×10^7	2.1×10^8	6.6×10^7	9.7×10^7	1.5×10^8
Derwent	5.2×10^6	3.5×10^7	5.9×10^6	1.1×10^7	3.0×10^7

From: Hudson-Edwards et al. (1999) Hydrological Processes, 13, 1087-1102.

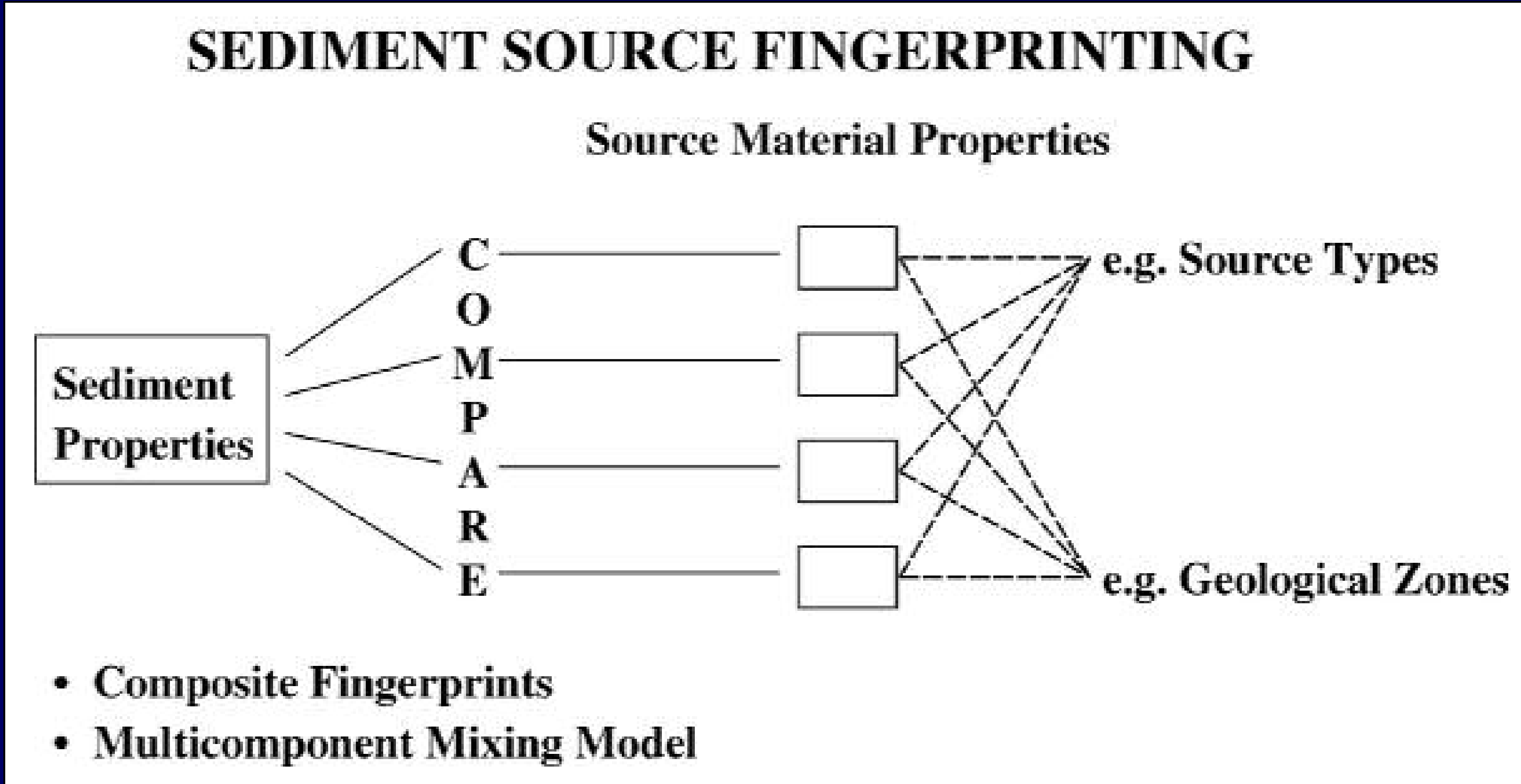
Historical Contamination

This was recognised to be a problem in many river basins, particularly industrialised river basins.

Tools for determining contaminant sources and tracing contamination input.

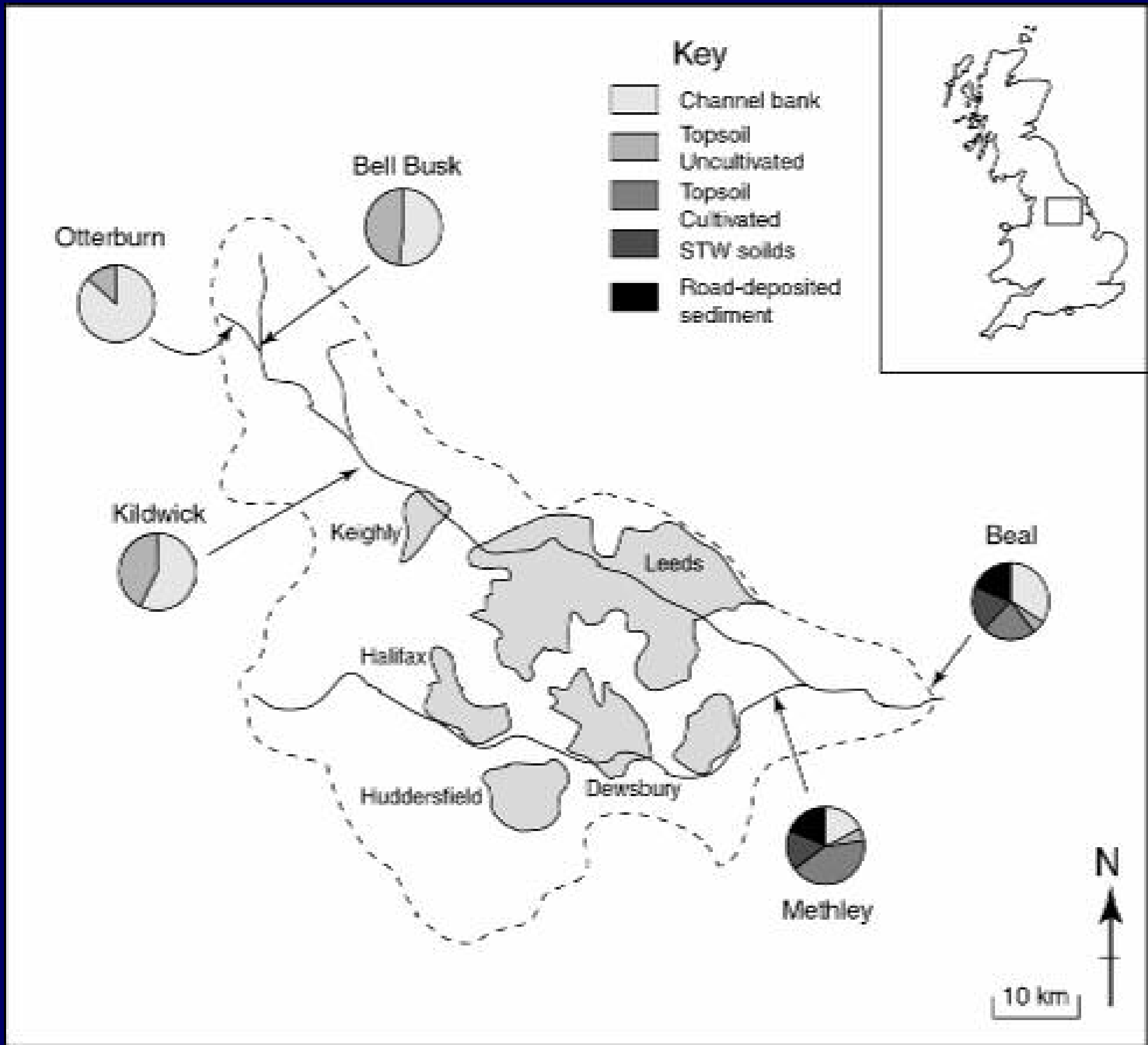
Source Discrimination – *Fingerprinting*

Fingerprinting of sediment sources has proven a useful and powerful tool.



From Walling et al. (2003) PSYCHIC presentation.

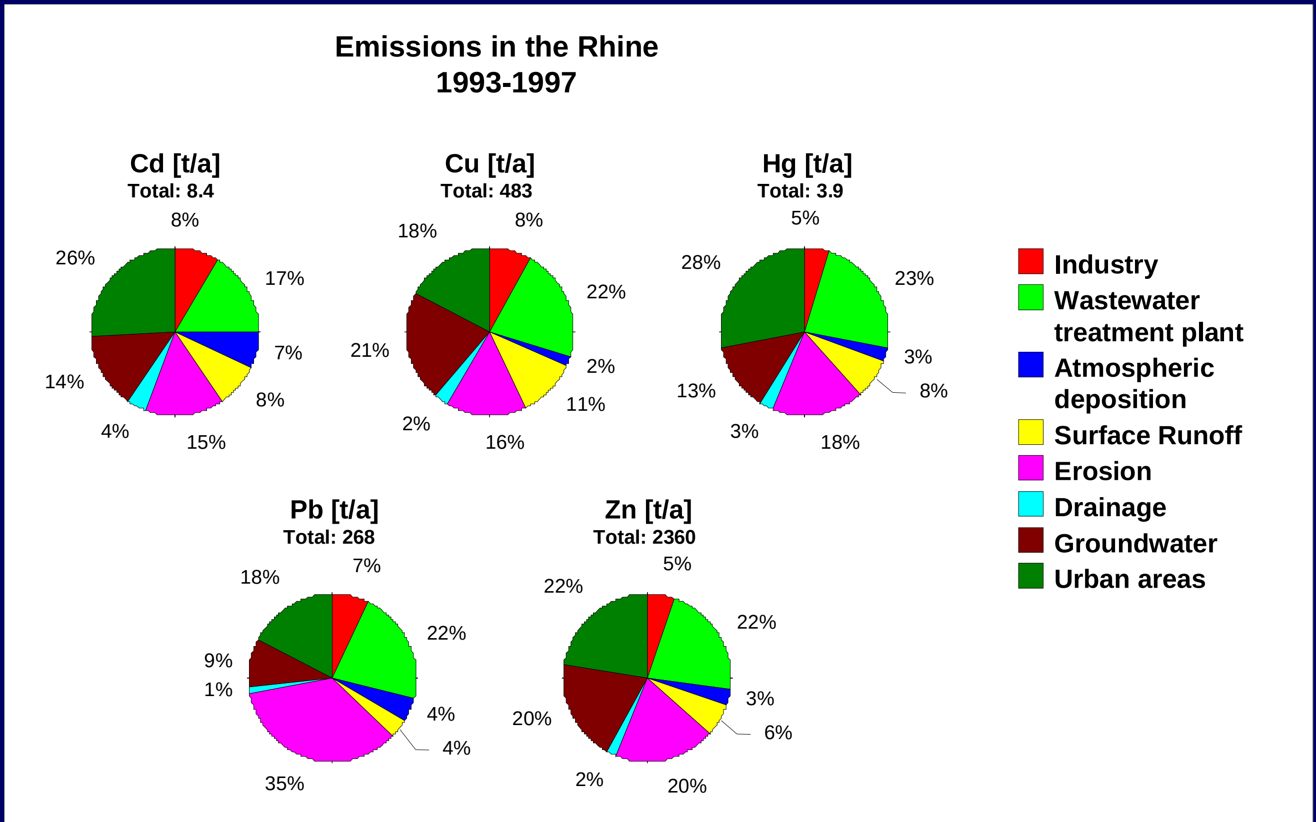
Sediment Source Fingerprinting, e.g. urban river basin



After: Carter et al. (2003) Science of the Total Environment,

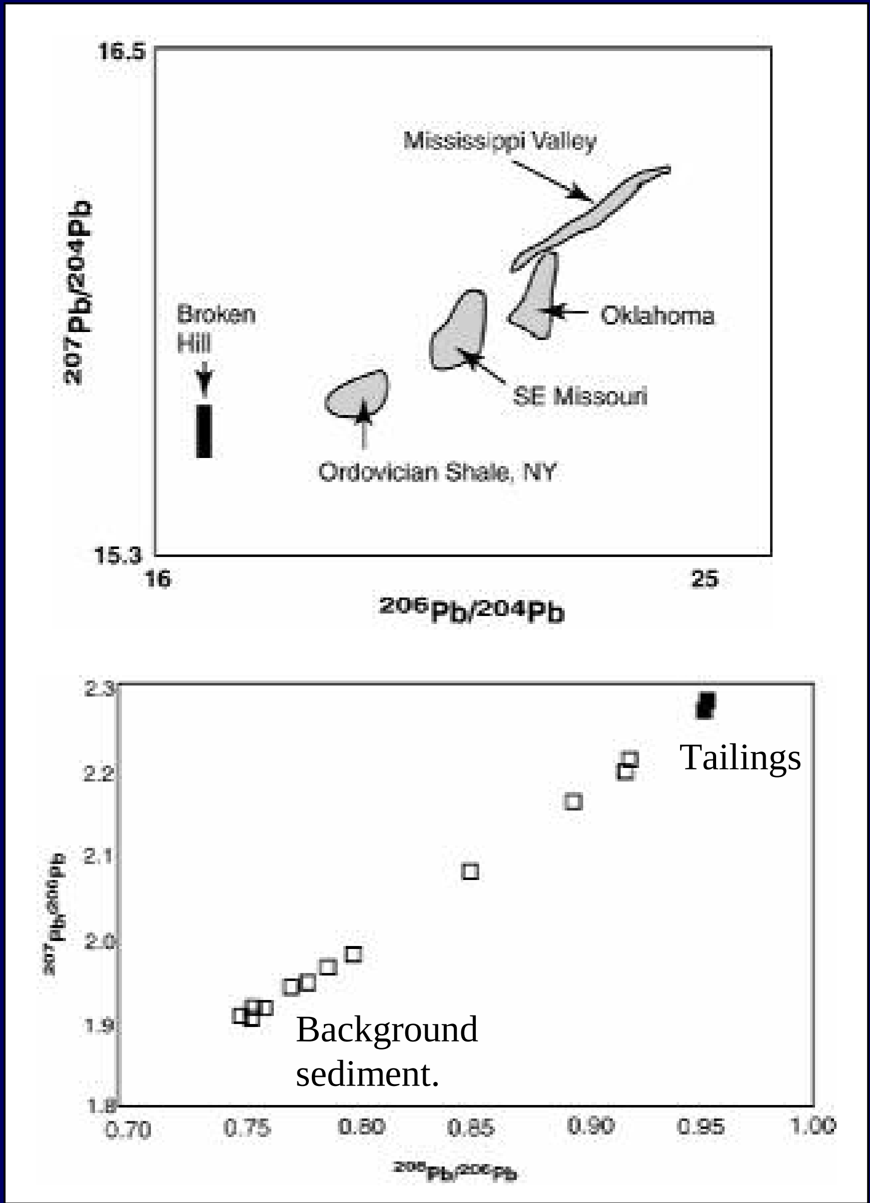
Immission/Emission Analysis

This method considers inputs of contaminants from both point and diffuse sources, using monitoring data from these, and models the total load of the river basin to statistically quantify the relative importance of each on a basin scale.



From: Salomons and Gandrass, 2001.

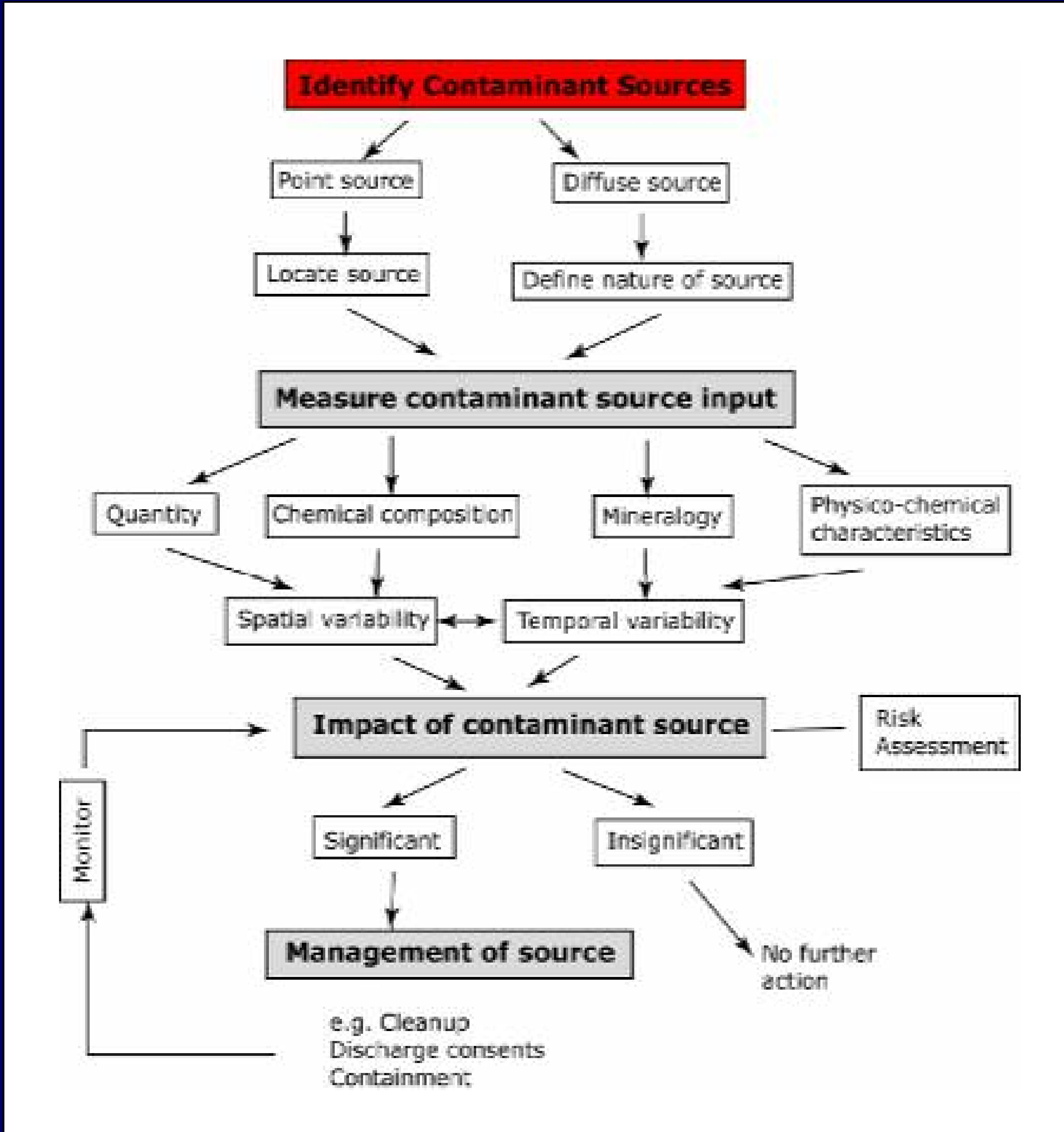
Source Fingerprints - *Stable Isotopes*



Stable isotopes of Pb (and other metals) have been increasingly used to fingerprint contaminant sources.

Discrimination of sources is possible.

Decision making framework: Contaminant sources

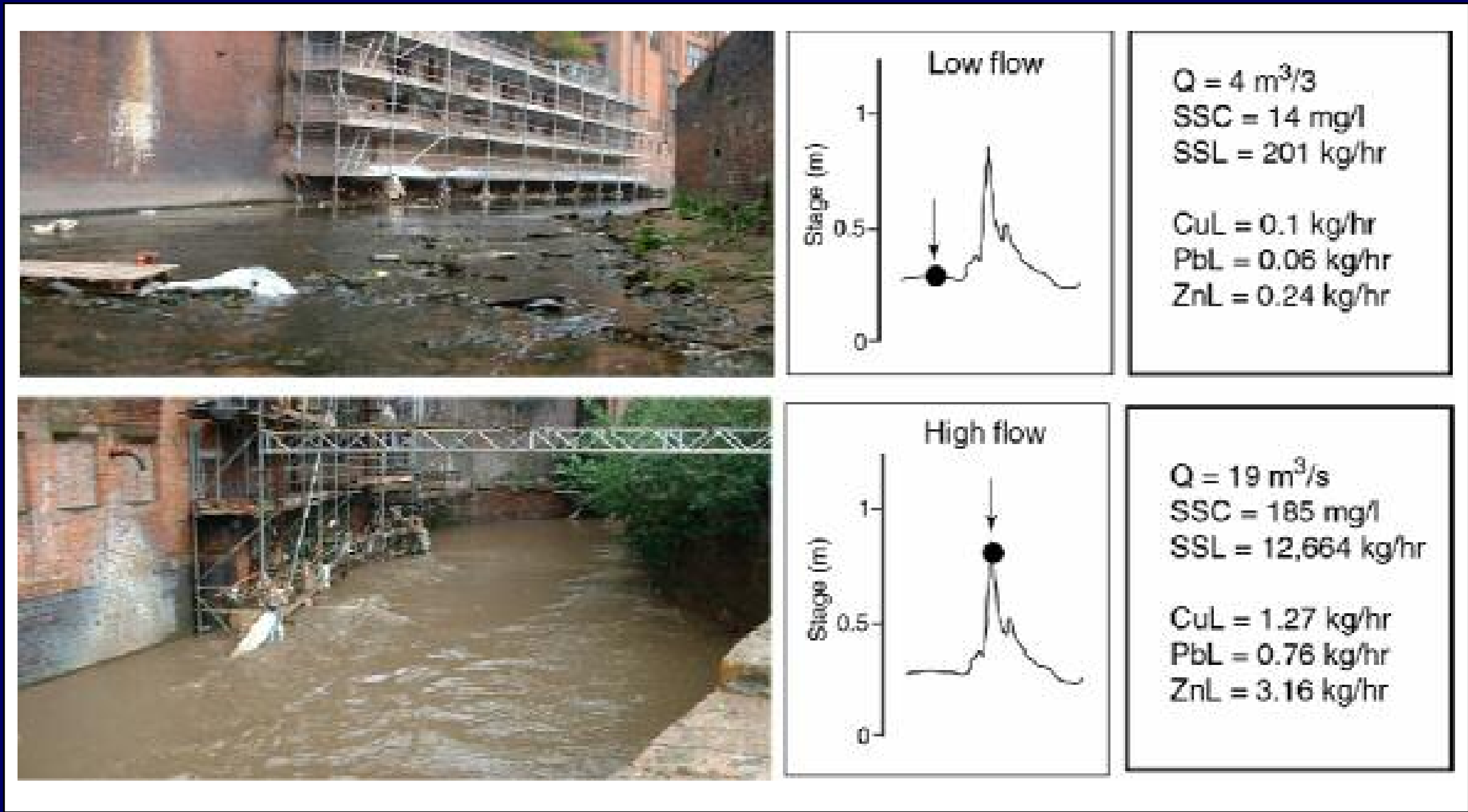


Recognised that a number of key aspects of sources need to be identified in order to effectively manage/remediate at the basin scale.

Transfers

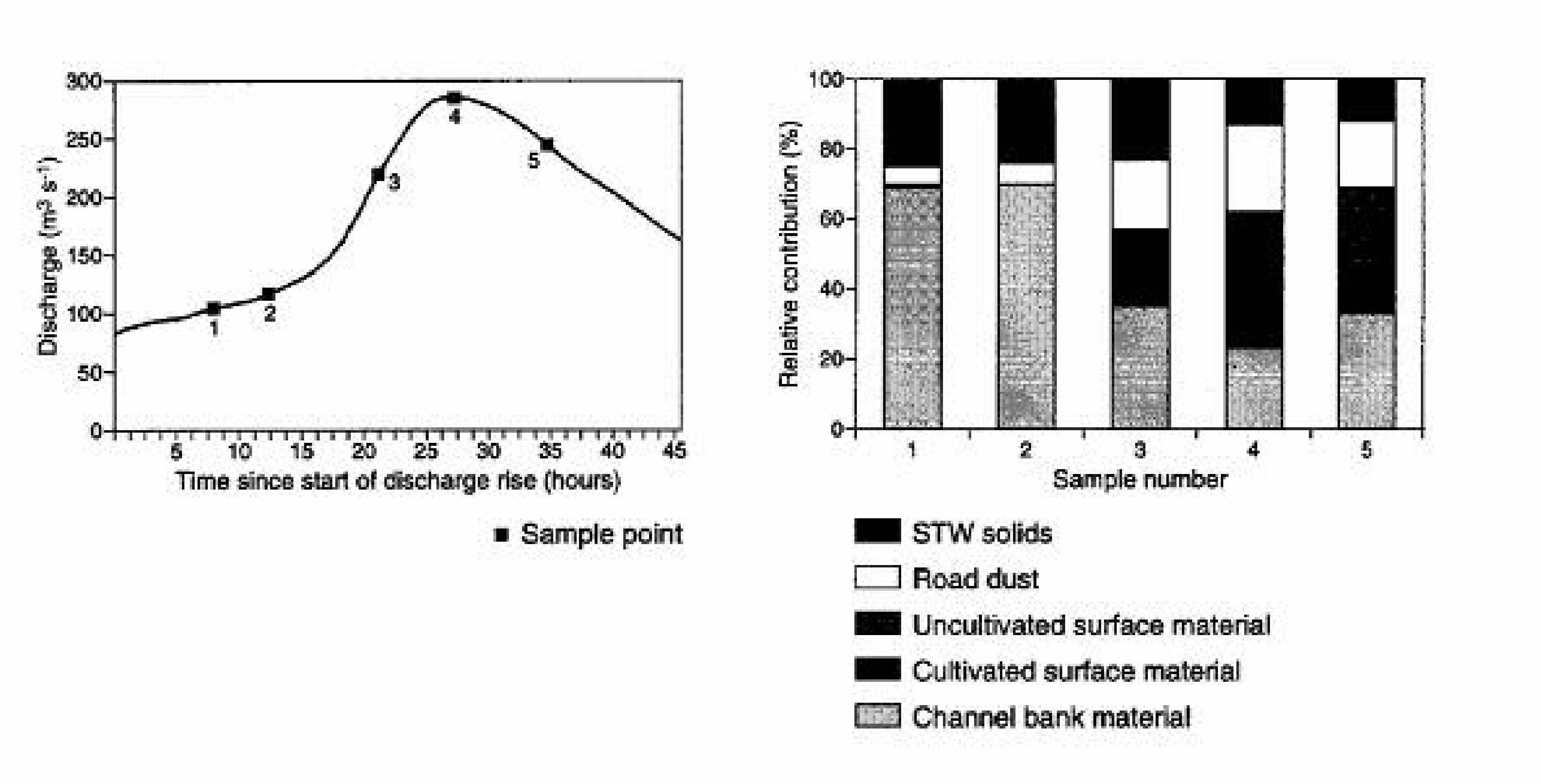
On a river basin-scale what contaminant and sediment transfer processes do we need to know more about?

High Magnitude, Low Frequency Events



Such events in river basins play a major role in contaminant and sediment transfer

High Magnitude, Low Frequency Events

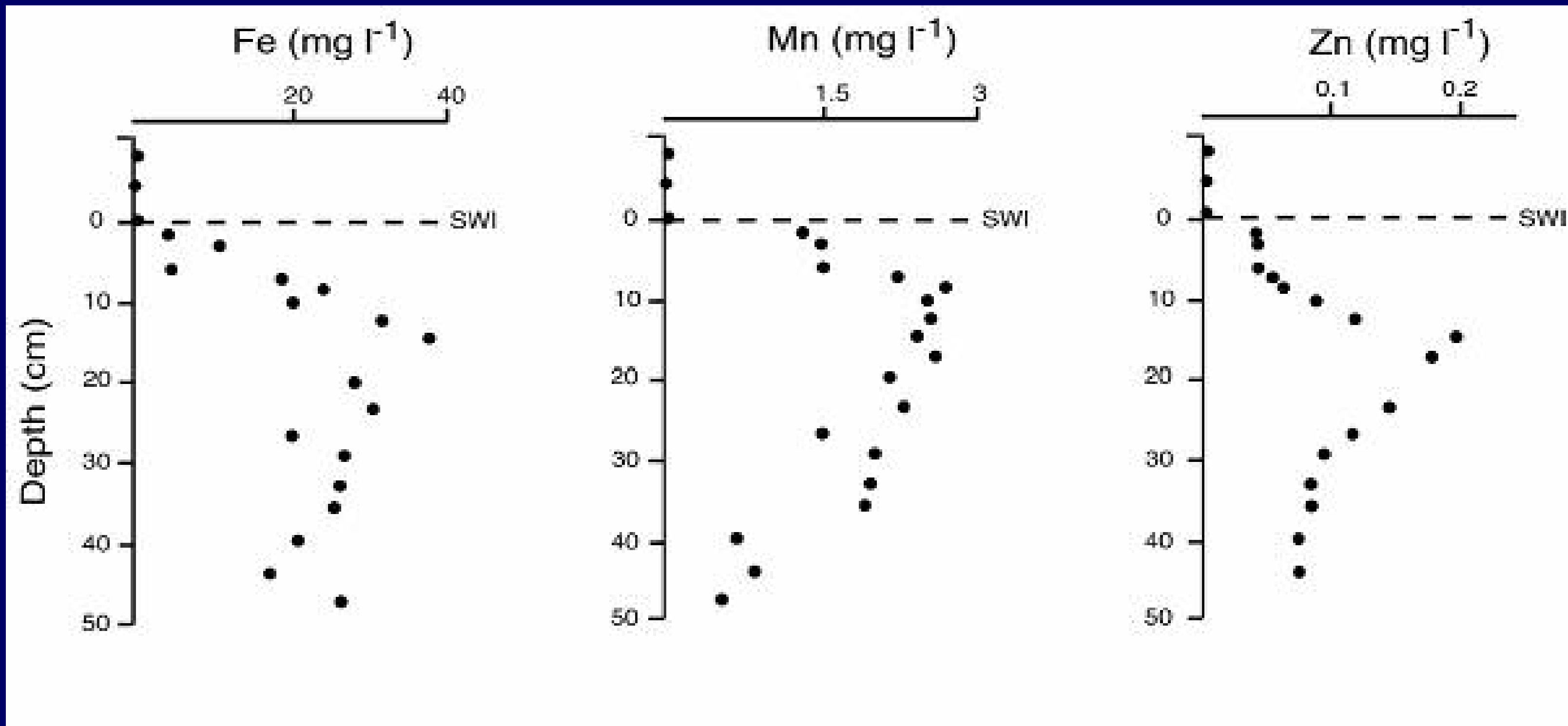


From Carter et al. (2003), *The Science of the Total Environment*, **314-316**, 513-534

Major changes in contaminant sourcing, routing and transfer are observed during these events.

Sediment-Water Interactions

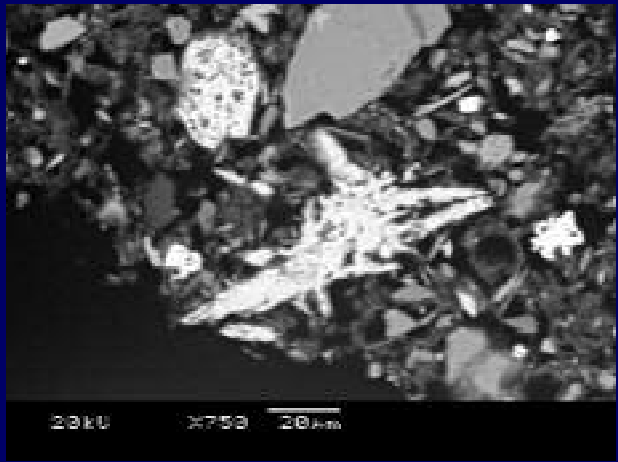
Early diagenesis results in contaminant release into river basins.

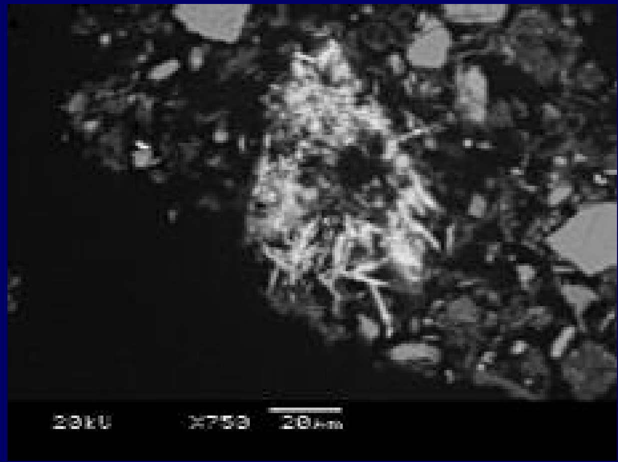


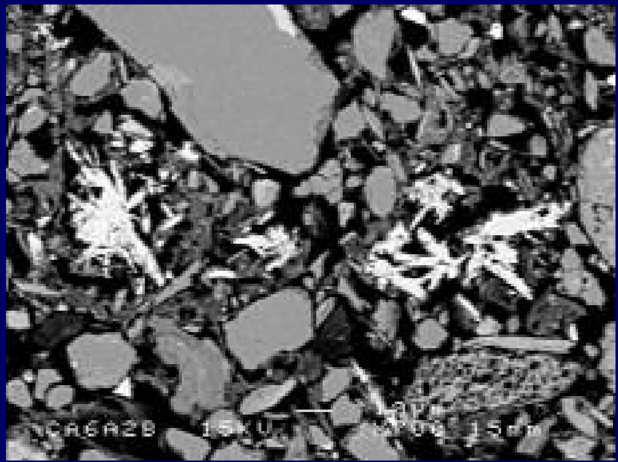
For example, bacterial Fe(III) reduction, Mn(IV) reduction, sulphate reduction and methanogenesis release contaminants into porewaters.

Sediment-Water Interactions

Early diagenetic mineral precipitates also play a role by removing contaminants from river basins.







Conclusions

1

A good understanding of the types of contaminant sources to sediments available. But, a need for improved methods of quantifying the relative importance of these sources in a river basin, especially diffuse sources.

2

Growing recognition that much sediment contamination is historical in nature, and that much of this contamination is being re-distributed into the river basin.

3

Whilst contaminant transfer processes are well understood, detailed monitoring and measurement at the most appropriate temporal scales are largely lacking (e.g. many monitoring programmes miss high magnitude, short-lived events).

4

Sediment-water (biochemical) interactions that significantly modify contaminant speciation and mineralogical associations and need to be incorporated into basin-scale contaminant transfer models.